Chapter 4: Forces Between Particles

CHAPTER OUTLINE
4.1 Noble Gas Configurations 4.7 Polyatomic Ions
4.2 Ionic Bonding 4.8 Shapes of Molecules and Polyatomic Ions
4.3 Ionic Compounds 4.9 The Polarity of Covalent Molecules
4.4 Naming Binary Ionic Compounds 4.10 More about Naming Compounds
4.5 The Smallest Unit of Ionic Compounds 4.11 Other Interparticle Forces
4.6 Covalent Bonding

LEARNING OBJECTIVES/ASSESSMENT
When you have completed your study of this chapter, you should be able to:
1. Draw correct Lewis structures for atoms of representative elements. (Section 4.1; Exercise 4.2)
2. Use electronic configurations to determine the number of electrons gained or lost by atoms as they achieve noble gas configurations. (Section 4.2; Exercise 4.12)
3. Use the octet rule to correctly predict the ions formed during the formation of ionic compounds, and write correct formulas for binary ionic compounds containing a representative metal and representative nonmetal. (Section 4.3; Exercises 4.20 and 4.22)
4. Correctly name binary ionic compounds. (Section 4.4; Exercise 4.30)
5. Determine formula weights for ionic compounds. (Section 4.5; Exercise 4.38)
6. Draw correct Lewis structures for covalent molecules. (Section 4.6; Exercise 4.48)
7. Draw correct Lewis structures for polyatomic ions. (Section 4.7; Exercise 4.50)
8. Use VSEPR theory to predict the shapes of molecules and polyatomic ions (Section 4.8; Exercises 4.52 and 4.54)
9. Use electronegativities to classify covalent bonds of molecules, and determine whether covalent molecules are polar or nonpolar. (Section 4.9; Exercises 4.58 and 4.64)
10. Write correct formulas for ionic compounds containing representative metals and polyatomic ions, and correctly name binary covalent compounds and compounds containing polyatomic ions. (Section 4.10; Exercises 4.66, 4.70, and 4.72)
11. Relate melting and boiling points of pure substances to the strength and type of interparticle forces present in the substances. (Section 4.11; Exercises 4.78 and 4.80)

LECTURE HINTS AND SUGGESTIONS
1. Emphasize how the reactivity of the noble gases is related to the stability of their electronic configurations. Use several examples of some simple ionic and covalent compounds to show how atoms exchange or share electrons in order to attain noble gas configurations.
2. Many students have difficulty recognizing the difference between a covalent molecule such as SO$_2$, sulfur trioxide, and a polyatomic anion, such as SO$_3^{2−}$. The importance of putting the charge on the ion should be stressed in this chapter. Also, point out the polyatomic anion is not a compound. It must be associated with a positive ion (usually a metal ion) to make a compound.
3. Have the students make some molecular models using balloons. Models of some type should be used in class when relating molecular shape to electronic structure. Stress the idea that the molecular shape is the result of electron pairs spreading out as far from each other as possible.
4. Be sure that the students understand that there is not really a clear division between covalent and ionic bonds, and that there is a continuous increase in ionic character as the electronegativity difference between the two bonding atoms increases. Generalizations can be made that ionic
Compounds are formed from a metal or NH₄⁺ and a non-metal, while covalent compounds are formed from two nonmetals.

**Solutions for the End of Chapter Exercises**

**Noble Gas Configurations (Section 4.1)**

4.1  
- a. lithium \( \text{Li} \)
- b. sodium \( \text{Na} \)
- c. chlorine \( \dot{\text{Cl}} \)
- d. boron \( \cdot \text{B} \)

4.2  
- a. arsenic \( \cdot \text{As} \)
- b. silicon \( \cdot \text{Si} \)
- c. lead \( \cdot \text{Pb} \)
- d. barium \( \cdot \text{Ba} \)

4.3  
- a. iodine \([\text{Kr}]5s^24d^{10}5p^5\)
- b. element number 38 (strontium) \([\text{Kr}]5s^2\)
- c. As \([\text{Ar}]4s^33d^{10}4p^3\)
- d. phosphorus \([\text{Ne}]3s^23p^3\)

4.4  
- a. element number 50 (tin) \([\text{Kr}]5s^24d^{10}5p^2\)
- b. Se \([\text{Ar}]4s^33d^{10}4p^4\)
- c. cesium \([\text{Xe}]6s^1\)
- d. iodine \([\text{Kr}]5s^24d^{10}5p^5\)

4.5  
- a. iodine \(\dot{\text{I}}\)
- b. element number 38 \(\cdot \text{Sr}\)
- c. As \(\cdot \text{As}\)
- d. phosphorus \(\cdot \text{P}\)

4.6  
- a. element number 50 (tin) \(\cdot \text{Sn}\)
- b. Se \(\cdot \text{Se}\)
- c. cesium \(\cdot \text{Cs}\)
- d. iodine \(\dot{\text{I}}\)

4.7  
- a. Any group IA(1) element \(\ddot{E}\)
- b. Any group IVA(14) element \(\cdot \dot{E}\)

4.8  
- a. Any group III A (13) element \(\cdot \dot{E}\)
- b. Any group VI A (16) element \(\cdot \dot{E}\)

**Ionic Bonding (Section 4.2)**

4.9  
- a. iodine \(1\)
- b. element number 38 (strontium) \(16\)
- c. As \(3\)
- d. phosphorus \(3\)
4.10  

<table>
<thead>
<tr>
<th>Added electrons</th>
<th>Removed electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. element number 50 (tin)</td>
<td>4</td>
</tr>
<tr>
<td>b. Se</td>
<td>2</td>
</tr>
<tr>
<td>c. cesium</td>
<td>31</td>
</tr>
<tr>
<td>d. iodine</td>
<td></td>
</tr>
</tbody>
</table>

4.11  

<table>
<thead>
<tr>
<th>Number of electrons lost/gained</th>
<th>Equation</th>
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</thead>
<tbody>
<tr>
<td>a. Ca</td>
<td>2 electrons lost</td>
</tr>
<tr>
<td>b. aluminum</td>
<td>3 electrons lost</td>
</tr>
<tr>
<td>c. fluorine</td>
<td>1 electron gained</td>
</tr>
<tr>
<td>d. element number 34</td>
<td>2 electrons gained</td>
</tr>
</tbody>
</table>

4.12  

<table>
<thead>
<tr>
<th>Number of electrons lost/gained</th>
<th>Equation</th>
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</thead>
<tbody>
<tr>
<td>a. Cs</td>
<td>1 electron lost</td>
</tr>
<tr>
<td>b. oxygen</td>
<td>2 electrons gained</td>
</tr>
<tr>
<td>c. element number 7</td>
<td>3 electrons gained</td>
</tr>
<tr>
<td>d. iodine</td>
<td>1 electron gained</td>
</tr>
</tbody>
</table>

4.13  

<table>
<thead>
<tr>
<th>Equation</th>
<th>Ion Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. A bromine atom that has gained one electron</td>
<td>Br + e^- → Br^-</td>
</tr>
<tr>
<td>b. A sodium atom that has lost one electron</td>
<td>Na → Na^+ + e^-</td>
</tr>
<tr>
<td>c. A sulfur atom that has gained two electrons</td>
<td>S + 2e^- → S^{2-}</td>
</tr>
</tbody>
</table>

4.14  

<table>
<thead>
<tr>
<th>Equation</th>
<th>Ion Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. A selenium atom that has gained two electrons</td>
<td>Se + 2e^- → Se^{2-}</td>
</tr>
<tr>
<td>b. A rubidium atom that has lost one electron</td>
<td>Rb → Rb^+ + e^-</td>
</tr>
<tr>
<td>c. An aluminum atom that has lost three electrons</td>
<td>Al → Al^{3+} + 3e^-</td>
</tr>
</tbody>
</table>

4.15  

<table>
<thead>
<tr>
<th>Element</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. E</td>
<td>+1 fluorine</td>
</tr>
<tr>
<td>b. E^{2+}</td>
<td>beryllium</td>
</tr>
</tbody>
</table>

4.16  

<table>
<thead>
<tr>
<th>Element</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. E^{2-}</td>
<td>sulfur</td>
</tr>
<tr>
<td>b. E^{3+}</td>
<td>aluminum</td>
</tr>
</tbody>
</table>

4.17  

<table>
<thead>
<tr>
<th>Element</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Mg^{2+}</td>
<td>neon</td>
</tr>
<tr>
<td>b. Te^{2-}</td>
<td>xenon</td>
</tr>
</tbody>
</table>

4.18  

<table>
<thead>
<tr>
<th>Element</th>
<th>Charge</th>
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</thead>
<tbody>
<tr>
<td>a. Li^+</td>
<td>helium</td>
</tr>
<tr>
<td>b. I^-</td>
<td>xenon</td>
</tr>
</tbody>
</table>
IONIC COMPOUNDS (SECTION 4.3)

4.19

<table>
<thead>
<tr>
<th>Cation formation</th>
<th>Anion formation</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Mg and S</td>
<td>Mg → Mg(^{2+}) + 2e(^-)</td>
<td>S + 2e(^-) → S(^2-)</td>
</tr>
<tr>
<td>b. strontium and nitrogen</td>
<td>Sr → Sr(^{2+}) + 2e(^-)</td>
<td>N + 3e(^-) → N(^3-)</td>
</tr>
<tr>
<td>c. elements number 3 and 34</td>
<td>Li → Li(^+) + e(^-)</td>
<td>Se + 2e(^-) → Se(^2-)</td>
</tr>
</tbody>
</table>

4.20

<table>
<thead>
<tr>
<th>Cation formation</th>
<th>Anion formation</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Ba and F</td>
<td>Ba → Ba(^{2+}) + 2e(^-)</td>
<td>F + e(^-) → F(^-)</td>
</tr>
<tr>
<td>b. potassium and bromine</td>
<td>K → K(^+) + e(^-)</td>
<td>Br + e(^-) → Br(^-)</td>
</tr>
<tr>
<td>c. elements number 13 and 35</td>
<td>Al → Al(^{3+}) + 3e(^-)</td>
<td>Br + e(^-) → Br(^-)</td>
</tr>
</tbody>
</table>

4.21

<table>
<thead>
<tr>
<th>Cation formation</th>
<th>Anion formation</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. S(_2^-)</td>
<td>SrS</td>
<td></td>
</tr>
<tr>
<td>b. Br(^-)</td>
<td>SrBr(_2)</td>
<td></td>
</tr>
<tr>
<td>c. N(^3-)</td>
<td>SrN(_2)</td>
<td></td>
</tr>
<tr>
<td>d. Cl(^-)</td>
<td>SrCl(_2)</td>
<td></td>
</tr>
</tbody>
</table>

4.22

<table>
<thead>
<tr>
<th>Cation formation</th>
<th>Anion formation</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Te(_2^-)</td>
<td>BaTe</td>
<td></td>
</tr>
<tr>
<td>b. N(^3-)</td>
<td>Ba(_3)N(_2)</td>
<td></td>
</tr>
<tr>
<td>c. F(^-)</td>
<td>BaF(_2)</td>
<td></td>
</tr>
<tr>
<td>d. P(^3-)</td>
<td>Ba(_3)P(_2)</td>
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4.23

<table>
<thead>
<tr>
<th>Cation formation</th>
<th>Anion formation</th>
<th>Binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. HF</td>
<td>binary</td>
<td></td>
</tr>
<tr>
<td>b. OF(_2)</td>
<td>binary</td>
<td></td>
</tr>
<tr>
<td>c. H(_2)SO(_4)</td>
<td>not binary</td>
<td></td>
</tr>
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</table>

4.24

<table>
<thead>
<tr>
<th>Cation formation</th>
<th>Anion formation</th>
<th>Binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. PbO(_2)</td>
<td>binary</td>
<td></td>
</tr>
<tr>
<td>b. CuCl(_2)</td>
<td>binary</td>
<td></td>
</tr>
<tr>
<td>c. KNO(_3)</td>
<td>not binary</td>
<td></td>
</tr>
</tbody>
</table>

NAMING BINARY IONIC COMPOUNDS (SECTION 4.4)

4.25

<table>
<thead>
<tr>
<th>Cation formation</th>
<th>Anion formation</th>
<th>Binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Ca(^{2+})</td>
<td>calcium ion</td>
<td></td>
</tr>
<tr>
<td>b. K(^+)</td>
<td>potassium ion</td>
<td></td>
</tr>
<tr>
<td>c. Al(^{3+})</td>
<td>aluminum ion</td>
<td></td>
</tr>
<tr>
<td>d. Rb(^+)</td>
<td>rubidium ion</td>
<td></td>
</tr>
</tbody>
</table>

4.26

<table>
<thead>
<tr>
<th>Cation formation</th>
<th>Anion formation</th>
<th>Binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Li(^+)</td>
<td>lithium ion</td>
<td></td>
</tr>
<tr>
<td>b. Mg(^{2+})</td>
<td>magnesium ion</td>
<td></td>
</tr>
<tr>
<td>c. Ba(^{2+})</td>
<td>barium ion</td>
<td></td>
</tr>
<tr>
<td>d. Cs(^+)</td>
<td>cesium ion</td>
<td></td>
</tr>
</tbody>
</table>

4.27

<table>
<thead>
<tr>
<th>Cation formation</th>
<th>Anion formation</th>
<th>Binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Cl(^-)</td>
<td>chloride ion</td>
<td></td>
</tr>
<tr>
<td>b. N(^3-)</td>
<td>nitride ion</td>
<td></td>
</tr>
<tr>
<td>c. S(_2^-)</td>
<td>sulfide ion</td>
<td></td>
</tr>
<tr>
<td>d. Se(_2^-)</td>
<td>selenide ion</td>
<td></td>
</tr>
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</table>

4.28

<table>
<thead>
<tr>
<th>Cation formation</th>
<th>Anion formation</th>
<th>Binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Br(^-)</td>
<td>bromide ion</td>
<td></td>
</tr>
<tr>
<td>b. O(_2^-)</td>
<td>oxide ion</td>
<td></td>
</tr>
<tr>
<td>c. p(_3^-)</td>
<td>phosphide ion</td>
<td></td>
</tr>
<tr>
<td>d. Te(_2^-)</td>
<td>telluride ion</td>
<td></td>
</tr>
</tbody>
</table>

4.29

<table>
<thead>
<tr>
<th>Cation formation</th>
<th>Anion formation</th>
<th>Binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. K(_2)O</td>
<td>potassium oxide</td>
<td></td>
</tr>
<tr>
<td>b. SrCl(_2)</td>
<td>strontium chloride</td>
<td></td>
</tr>
<tr>
<td>c. Al(_2)O(_3)</td>
<td>aluminum oxide</td>
<td></td>
</tr>
<tr>
<td>d. LiBr</td>
<td>lithium bromide</td>
<td></td>
</tr>
<tr>
<td>e. CaS</td>
<td>calcium sulfide</td>
<td></td>
</tr>
</tbody>
</table>
Forces Between Particles

### 4.30

| a. MgO | magnesium oxide |
| b. CaS | calcium sulfide |
| c. ZnO | zinc oxide |
| d. AlCl₃ | aluminum chloride |
| e. Na₃N | sodium nitride |

### 4.31

| a. CrCl₂ and CrCl₃ | chromium (II) chloride and chromium (III) chloride |
| b. CoS and Co₂S₃ | cobalt (II) sulfide and cobalt (III) sulfide |
| c. FeO and Fe₂O₃ | iron (II) oxide and iron (III) oxide |
| d. PbCl₂ and PbCl₄ | lead (II) chloride and lead (IV) chloride |

### 4.32

| a. CrCl₂ and CrCl₃ | chromous chloride and chromic chloride |
| b. CoS and Co₂S₃ | cobaltous sulfide and cobaltic sulfide |
| c. FeO and Fe₂O₃ | ferrous oxide and ferric oxide |
| d. PbCl₂ and PbCl₄ | plumbous chloride and plumbic chloride |

### 4.33

| a. SnS and SnS₂ | stannous sulfide and stannic sulfide |
| b. FeCl₂ and FeCl₃ | ferrous chloride and ferric chloride |
| c. Cu₂O and CuO | cuprous oxide and cupric oxide |
| d. AuCl and AuCl₃ | aurous chloride and auric chloride |

### 4.34

| a. MnCl₂ | manganese(II) chloride |
| b. FeS₃ | iron(III) sulfide |
| c. CrO | chromium(II) oxide |
| d. SnCl₂ | tin(II) chloride |

### 4.35

| a. MnCl₂ | manganese(II) chloride |
| b. FeS₃ | iron(III) sulfide |
| c. CrO | chromium(II) oxide |
| d. SnCl₂ | tin(II) chloride |

### 4.36

| a. Hg₂O | mercury(I) oxide |
| b. PbO | lead(II) oxide |
| c. PtI₄ | platinum (IV) iodide |

### THE SMALLEST UNIT OF IONIC COMPOUNDS (SECTION 4.5)

(Note: Based on Section 2.6, calculations involving atomic weights, molecular weights, and Avogadro’s number will use three significant figures.)

### 4.37

| a. Na₂O | (2 × 23.0 u) + (1 × 16.0 u) = 62.0 u |
| b. Fe₂O | (1 × 55.8 u) + (1 × 16.0 u) = 71.8 u |
| c. PbS₂ | (1 × 207 u) + (2 × 32.1 u) = 271 u |
| d. AlCl₃ | (1 × 27.0 u) + (3 × 35.5 u) = 134 u |

### 4.38

| a. KF | (1 × 39.1 u) + (1 × 19.0 u) = 58.1 u |
| b. Be₃N₂ | (3 × 9.01 u) + (2 × 14.0 u) = 55.0 u |
| c. Li₃P | (3 × 6.94 u) + (1 × 31.0 u) = 51.8 u |
| d. Cu₂O | (2 × 63.5 u) + (1 × 16.0 u) = 143 u |
4.39  
\[ \text{a. Na}_2\text{O} \quad \text{b. FeO} \quad \text{c. PbS}_2 \quad \text{d. AlCl}_3 \]  
\[ \text{Na}^+ \text{, O}^2- \quad \text{Fe}^{2+} \text{, O}^2- \quad \text{Pb}^{4+} \text{, S}^2- \quad \text{Al}^{3+} \text{, Cl}^- \]

4.40  
\[ \text{a. KF} \quad \text{b. Be}_3\text{N}_2 \quad \text{c. Li}_3\text{P} \quad \text{d. Cu}_2\text{O} \]  
\[ \text{K}^+ \text{, F}^- \quad \text{Be}^{2+} \text{, N}^3- \quad \text{Li}^+ \text{, P}^{3-} \quad \text{Cu}^{2+} \text{, O}^2- \]

4.41  
\[ \text{a. Na}_2\text{O} \quad \text{b. FeO} \quad \text{c. PbS}_2 \quad \text{d. AlCl}_3 \]  
\[ \begin{array}{c} 2 \times 23.0 \text{ g} = 46.0 \text{ g Na}^+ \quad 1 \times 16.0 \text{ g} = 16.0 \text{ g O}^2- \\ 1 \times 55.8 \text{ g} = 55.8 \text{ g Fe}^{2+} \quad 1 \times 16.0 \text{ g} = 16.0 \text{ g O}^2- \\ 1 \times 207 \text{ g} = 207 \text{ g Pb}^{4+} \quad 2 \times 32.1 \text{ g} = 64.2 \text{ g S}^2- \\ 1 \times 27.0 \text{ g} = 27.0 \text{ g Al}^{3+} \quad 3 \times 35.5 \text{ g} = 106.5 \text{ g Cl}^- \end{array} \]

4.42  
\[ \text{a. KF} \quad \text{b. Be}_3\text{N}_2 \quad \text{c. Li}_3\text{P} \quad \text{d. Cu}_2\text{O} \]  
\[ \begin{array}{c} 1 \times 39.1 \text{ g} = 39.1 \text{ g K}^+ \quad 1 \times 19.0 \text{ g} = 19.0 \text{ g F}^- \\ 3 \times 9.01 \text{ g} = 27.0 \text{ g Be}^{2+} \quad 2 \times 14.0 \text{ g} = 28.0 \text{ g N}^3- \\ 3 \times 6.94 \text{ g} = 20.8 \text{ g Li}^+ \quad 1 \times 31.0 \text{ g} = 31.0 \text{ g P}^{3-} \\ 2 \times 63.5 \text{ g} = 127 \text{ g Cu}^{2+} \quad 1 \times 16.0 \text{ g} = 16.0 \text{ g O}^2- \end{array} \]

4.43  
\[ \text{a. Na}_2\text{O} \quad \text{b. FeO} \quad \text{c. PbS}_2 \quad \text{d. AlCl}_3 \]  
\[ \begin{array}{c} 1.00 \text{ mole Na}_2\text{O} \times \frac{2.02 \times 10^{23} \text{ formula units}}{1 \text{ mole Na}_2\text{O}} \times \frac{2 \text{ Na}^+ \text{ ions}}{1 \text{ formula unit Na}_2\text{O}} = 1.20 \times 10^{24} \text{ Na}^+ \text{ ions} \\ 1.00 \text{ mole Na}_2\text{O} \times \frac{2.02 \times 10^{23} \text{ formula units}}{1 \text{ mole Na}_2\text{O}} \times \frac{1 \text{ O}^2- \text{ ion}}{1 \text{ formula unit Na}_2\text{O}} = 6.02 \times 10^{23} \text{ O}^2- \text{ ions} \\ 1.00 \text{ mole FeO} \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mole FeO}} \times \frac{1 \text{ Fe}^{2+} \text{ ion}}{1 \text{ formula unit FeO}} = 6.02 \times 10^{23} \text{ Fe}^{2+} \text{ ions} \\ 1.00 \text{ mole FeO} \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mole FeO}} \times \frac{1 \text{ O}^2- \text{ ion}}{1 \text{ formula unit FeO}} = 6.02 \times 10^{23} \text{ O}^2- \text{ ions} \\ 1.00 \text{ mole PbS}_2 \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mole PbS}_2} \times \frac{1 \text{ Pb}^{4+} \text{ ion}}{1 \text{ formula unit PbS}_2} = 6.02 \times 10^{23} \text{ Pb}^{4+} \text{ ions} \\ 1.00 \text{ mole PbS}_2 \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mole PbS}_2} \times \frac{2 \text{ S}^2- \text{ ions}}{1 \text{ formula unit PbS}_2} = 1.20 \times 10^{24} \text{ S}^2- \text{ ions} \\ 1.00 \text{ mole AlCl}_3 \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mole AlCl}_3} \times \frac{1 \text{ Al}^{3+} \text{ ion}}{1 \text{ formula unit AlCl}_3} = 6.02 \times 10^{23} \text{ Al}^{3+} \text{ ions} \\ 1.00 \text{ mole AlCl}_3 \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mole AlCl}_3} \times \frac{3 \text{ Cl}^- \text{ ions}}{1 \text{ formula unit AlCl}_3} = 1.81 \times 10^{24} \text{ Cl}^- \text{ ions} \\ 1.00 \text{ mole KF} \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mole KF}} \times \frac{1 \text{ K}^+ \text{ ion}}{1 \text{ formula unit KF}} = 6.02 \times 10^{23} \text{ K}^+ \text{ ions} \\ 1.00 \text{ mole KF} \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mole KF}} \times \frac{1 \text{ F}^- \text{ ion}}{1 \text{ formula unit KF}} = 6.02 \times 10^{23} \text{ F}^- \text{ ions} \end{array} \]
b. Be\textsubscript{3}N\textsubscript{2}
\[ 1.00 \text{ mole Be}_3\text{N}_2 \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mole Be}_3\text{N}_2} \times \frac{3 \text{ Be}^{2+} \text{ ions}}{1 \text{ formula unit Be}_3\text{N}_2} = 1.81 \times 10^{24} \text{ Be}^{2+} \text{ ions} \]
\[ 1.00 \text{ mole Be}_3\text{N}_2 \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mole Be}_3\text{N}_2} \times \frac{2 \text{ N}^{3-} \text{ ions}}{1 \text{ formula unit Be}_3\text{N}_2} = 1.20 \times 10^{24} \text{ N}^{3-} \text{ ions} \]

c. Li\textsubscript{3}P
\[ 1.00 \text{ mole Li}_3\text{P} \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mole Li}_3\text{P}} \times \frac{3 \text{ Li}^+ \text{ ions}}{1 \text{ formula unit Li}_3\text{P}} = 1.81 \times 10^{24} \text{ Li}^+ \text{ ions} \]
\[ 1.00 \text{ mole Li}_3\text{P} \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mole Li}_3\text{P}} \times \frac{1 \text{ P}^{3-} \text{ ion}}{1 \text{ formula unit Li}_3\text{P}} = 6.02 \times 10^{23} \text{ P}^{3-} \text{ ions} \]

d. Cu\textsubscript{2}O
\[ 1.00 \text{ mole Cu}_2\text{O} \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mole Cu}_2\text{O}} \times \frac{2 \text{ Cu}^+ \text{ ions}}{1 \text{ formula unit Cu}_2\text{O}} = 1.20 \times 10^{24} \text{ Cu}^+ \text{ ions} \]
\[ 1.00 \text{ mole Cu}_2\text{O} \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mole Cu}_2\text{O}} \times \frac{1 \text{ O}^{2-} \text{ ion}}{1 \text{ formula unit Cu}_2\text{O}} = 6.02 \times 10^{23} \text{ O}^{2-} \text{ ions} \]

**COVALENT BONDING (SECTION 4.6)**

4.45 \[ \begin{array}{cc}
\text{I} & + \\
\text{I} & \rightarrow \\
\text{I} & \end{array} \]

4.46 \[ \begin{array}{cc}
\text{S} & \rightarrow \\
\text{S} & \end{array} \]

4.47 a. HF
\[ \begin{array}{cc}
\text{H} & \end{array} \]

b. IBr
\[ \begin{array}{cc}
\text{I} & - \\
\text{Br} & \end{array} \]

c. PH\textsubscript{3} (each H atom is bonded to the P atom)
\[ \begin{array}{cc}
\text{H} & - \\
\text{P} & - \\
\text{H} & \end{array} \]

d. HClO\textsubscript{3} (the O atoms are each bonded to the Cl, and the H is bonded to one of the O atoms)
\[ \begin{array}{cc}
\text{O} & - \\
\text{Cl} & - \\
\text{O} & \end{array} \]

4.48 a. H\textsubscript{2}S (each H atom is bonding to the S atom)
\[ \begin{array}{cc}
\text{H} & - \\
\text{S} & - \\
\text{H} & \end{array} \]

b. CIF
\[ \begin{array}{cc}
\text{Cl} & - \\
\text{I} & - \\
\text{Cl} & \end{array} \]

c. HBr
\[ \begin{array}{cc}
\text{H} & - \\
\text{Br} & - \\
\text{H} & \end{array} \]

d. HClO (the H and Cl are each bonded to O)
\[ \begin{array}{cc}
\text{Cl} & - \\
\text{O} & - \\
\text{Cl} & \end{array} \]
Chapter 4

POLYATOMIC IONS (SECTION 4.7)

4.49  a. ClO$_3^-$ (each O atom is bonded to the Cl atom)

\[
\begin{array}{c}
\text{Cl} \quad \text{O} \quad \text{O} \\
\vdots \quad \vdots \quad \vdots \\
\text{O} \quad \text{Cl} \quad \text{O}
\end{array}
\]

b. CN$^-$

c. CO$_3^{2-}$ (each O atom is bonded to the C atom)

\[
\begin{array}{c}
\text{O} \quad \text{C} \quad \text{O} \\
\vdots \quad \vdots \quad \vdots \\
\text{O} \quad \text{O} \quad \text{O}
\end{array}
\]

4.50  a. PH$_4^+$ (each H atom is bonded to the P atom)

\[
\begin{array}{c}
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\
\vdots \quad \vdots \quad \vdots \quad \vdots \\
\text{H} \quad \text{P} \quad \text{H}
\end{array}
\]

b. HPO$_4^{2-}$ (each O atom is bonded to the P atom, and the H atom is bonded to an O atom)

\[
\begin{array}{c}
\text{O} \quad \text{P} \quad \text{O} \quad \text{O} \\
\vdots \quad \vdots \quad \vdots \quad \vdots \\
\text{O} \quad \text{P} \quad \text{O} \quad \text{H}
\end{array}
\]

c. HSO$_4^-$ (each O atom is bonded to the S atom, and the H atom is bonded to an O atom)

\[
\begin{array}{c}
\text{O} \quad \text{S} \quad \text{O} \quad \text{H} \\
\vdots \quad \vdots \quad \vdots \quad \vdots \\
\text{O} \quad \text{S} \quad \text{O} \quad \text{H}
\end{array}
\]

SHAPES OF MOLECULES AND POLYATOMIC IONS (SECTION 4.8)

4.51  a. O$_3$ (the O atoms are bonded together, like beads on a string)

\[
\begin{array}{c}
\text{O} \quad \text{O} \quad \text{O} \\
\vdots \quad \vdots \quad \vdots \\
\text{O} \quad \text{O} \quad \text{O}
\end{array}
\]

VSEPR: bent or angular

b. CS$_2$ (each S atom is bonded to the C atom)

\[
\begin{array}{c}
\text{S} \quad \text{C} \quad \text{S} \\
\vdots \quad \vdots \quad \vdots \\
\text{S} \quad \text{C} \quad \text{S}
\end{array}
\]

VSEPR: linear

c. SeO$_2$ (each O atom is bonded to the Se atom)

\[
\begin{array}{c}
\text{O} \quad \text{Se} \quad \text{O} \\
\vdots \quad \vdots \quad \vdots \\
\text{O} \quad \text{Se} \quad \text{O}
\end{array}
\]

VSEPR: bent or angular
Forces Between Particles

**4.52**

**a.** $\text{H}_2\text{S}$
  (each H atom is bonded to the S atom)

**b.** $\text{PCl}_3$
  (each Cl atom is bonded to the P atom)

**c.** $\text{OF}_2$
  (each F atom is bonded to the O atom)

**d.** $\text{SnF}_4$
  (each F atom is bonded to the Sn atom)

**4.53**

**a.** $\text{O}_3$
  (the O atoms are bonded together, like beads on a string)

**b.** $\text{SeO}_2$
  (each O atom is bonded to the Se atom)

**c.** $\text{PH}_3$
  (each H atom is bonded to the P atom)

**d.** $\text{SO}_3$
  (each O atom is bonded to the S atom)
4.54

<table>
<thead>
<tr>
<th>Lewis structure</th>
<th>3D Structure</th>
<th>VSEPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO₂⁻ (each O is bonded to N)</td>
<td><img src="image1" alt="Lewis structure" /></td>
<td>bent or angular</td>
</tr>
<tr>
<td>ClO₃⁻ (each O is bonded to Cl)</td>
<td><img src="image2" alt="Lewis structure" /></td>
<td>triangular pyramid with Cl at the top</td>
</tr>
<tr>
<td>CO₃²⁻ (each O is bonded to C)</td>
<td><img src="image3" alt="Lewis structure" /></td>
<td>flat triangle with C in the middle</td>
</tr>
<tr>
<td>H₂O⁺ (each H is bonded to O)</td>
<td><img src="image4" alt="Lewis structure" /></td>
<td>triangular pyramid with O at the top</td>
</tr>
</tbody>
</table>

4.55

<table>
<thead>
<tr>
<th>Lewis structure</th>
<th>3D Structure</th>
<th>VSEPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH₂⁺ (each H is bonded to N)</td>
<td><img src="image5" alt="Lewis structure" /></td>
<td>bent or angular</td>
</tr>
<tr>
<td>PO₃³⁻ (each O is bonded to P)</td>
<td><img src="image6" alt="Lewis structure" /></td>
<td>triangular pyramid with P at the top</td>
</tr>
<tr>
<td>BeCl₄²⁻ (each Cl is bonded to Be)</td>
<td><img src="image7" alt="Lewis structure" /></td>
<td>tetrahedral with Be in the center</td>
</tr>
<tr>
<td>ClO₄⁻ (each O is bonded to Cl)</td>
<td><img src="image8" alt="Lewis structure" /></td>
<td>tetrahedral with Cl in the center</td>
</tr>
</tbody>
</table>

THE POLARITY OF COVALENT MOLECULES (SECTION 4.9)

4.56

<table>
<thead>
<tr>
<th></th>
<th>ΔEN</th>
<th>The bonds in this molecule are nonpolar.</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. H—I</td>
<td>2.5 – 2.1 = 0.4</td>
<td></td>
</tr>
<tr>
<td>b. S=O</td>
<td>3.5 – 2.5 = 1.0</td>
<td></td>
</tr>
<tr>
<td>c. O=O</td>
<td>3.5 – 3.5 = 0</td>
<td></td>
</tr>
</tbody>
</table>
4.57

<table>
<thead>
<tr>
<th>Particle</th>
<th>ΔEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ClF</td>
<td>4.0 − 3.0 = 1.0</td>
</tr>
<tr>
<td>b. HSe</td>
<td>2.4 − 2.1 = 0.3</td>
</tr>
<tr>
<td>c. BH_{2}BH_{2}</td>
<td>2.1 − 2.0 = 0.1</td>
</tr>
</tbody>
</table>

4.58

<table>
<thead>
<tr>
<th>Substance</th>
<th>Calculation</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. KI</td>
<td>2.5 − 0.8 = 1.7</td>
<td>polar covalent</td>
</tr>
<tr>
<td>b. NH_{3}</td>
<td>3.0 − 2.1 = 0.9</td>
<td>polar covalent</td>
</tr>
<tr>
<td>c. CO</td>
<td>3.5 − 2.5 = 1.0</td>
<td>polar covalent</td>
</tr>
<tr>
<td>d. CaO</td>
<td>3.5 − 1.0 = 2.5</td>
<td>ionic</td>
</tr>
<tr>
<td>e. NO</td>
<td>3.5 − 3.0 = 0.5</td>
<td>polar covalent</td>
</tr>
</tbody>
</table>

4.59

<table>
<thead>
<tr>
<th>Substance</th>
<th>Calculation</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. PCl_{3}</td>
<td>3.0 − 2.1 = 0.9</td>
<td>polar covalent</td>
</tr>
<tr>
<td>b. H_{2}Se</td>
<td>2.4 − 2.1 = 0.3</td>
<td>polar covalent</td>
</tr>
<tr>
<td>c. MgCl_{2}</td>
<td>3.0 − 1.2 = 1.8</td>
<td>polar covalent</td>
</tr>
<tr>
<td>d. BeI_{2}</td>
<td>2.5 − 1.5 = 1.0</td>
<td>polar covalent</td>
</tr>
<tr>
<td>e. NCl_{3}</td>
<td>3.0 − 3.0 = 0</td>
<td>nonpolar covalent</td>
</tr>
</tbody>
</table>

4.60

| Substance | | Description |
|-----------|-----------------|
| a. H—I    | δ+ I—δ−H        | This is a polar molecule because the charge distribution from bond polarization is nonsymmetric. |
| b. S=O    | δ+ S—δ−O        | This is a polar molecule because the charge distribution from bond polarization is nonsymmetric. |
| c. O=O    | The bonds in this molecule are nonpolar. | This is a nonpolar molecule because the molecule does not have a charge distribution (the bonds are nonpolar). |

4.61

| Substance | | Description |
|-----------|-----------------|
| a. ClF    | δ+ F—δ−Cl       | This is a polar molecule because the charge distribution from bond polarization is nonsymmetric. |
| b. HSe    | δ+ H—δ−Se       | This is a polar molecule because the charge distribution from bond polarization is nonsymmetric. |
| c. BH_{2}BH_{2} | δ+ B—δ−H        | This is a nonpolar molecule because the charge distribution from bond polarization is symmetric. |
4.62
a. nitrogen and oxygen  
   \[ 3.5 - 3.0 = 0.5 \]  
   polar covalent
b. magnesium and oxygen  
   \[ 3.5 - 1.2 = 2.3 \]  
   ionic
c. N and H  
   \[ 3.0 - 2.1 = 0.9 \]  
   polar covalent

4.63
a. sulfur and oxygen  
   \[ 3.5 - 2.5 = 1.0 \]  
   polar covalent
b. aluminum and bromine  
   \[ 2.8 - 1.5 = 1.3 \]  
   polar covalent
c. C and Cl  
   \[ 3.0 - 2.5 = 0.5 \]  
   polar covalent

4.64
a. C\(\rightleftharpoons\)O  
   \(\delta^+\)\(\rightleftharpoons\)O\(\delta^-\)  
   polar molecule  
   (nonsymmetric charge distribution)
b. H\(\rightleftharpoons\)Se\(\rightleftharpoons\)H  
   \(\delta^+\)\(\rightleftharpoons\)Se\(\delta^-\)  
   polar molecule  
   (nonsymmetric charge distribution)
c. I\(\rightleftharpoons\)Al\(\rightleftharpoons\)I  
   \(\delta^-\)\(\rightleftharpoons\)Al\(\delta^+\)  
   nonpolar molecule  
   (symmetric charge distribution)

4.65
a. S\(\rightleftharpoons\)C\(\rightleftharpoons\)S  
   both elements have an electronegativity value of 2.5  
   nonpolar molecule  
   (no charge distribution; nonpolar bonds)
b. H\(\rightleftharpoons\)C\(\rightleftharpoons\)N  
   \(\delta^+\)\(\rightleftharpoons\)N\(\delta^-\)  
   polar molecule  
   (nonsymmetric charge distribution)
c. F\(\rightleftharpoons\)O\(\rightleftharpoons\)F  
   \(\delta^-\)\(\rightleftharpoons\)F\(\delta^+\)  
   polar molecule  
   (nonsymmetric charge distribution)

MORE ABOUT NAMING COMPOUNDS (SECTION 4.10)

4.66
a. NCl\(_3\)  
   nitrogen trichloride  
   SeF\(_4\)  
   sulfur tetrafluoride
d. SF\(_4\)  
   sulfur tetrafluoride
b. P\(_4\)O\(_6\)  
   tetraphosphorus hexoxide  
   ClO\(_2\)  
   chlorine dioxide
e. ClO\(_2\)  
   chlorine dioxide

4.67
a. SiO\(_2\)  
   silicon dioxide  
   d. AlBr\(_3\)  
   aluminum tribromide
b. SiF\(_4\)  
   silicon tetrafluoride  
   e. CBr\(_4\)  
   carbon tetrabromide
c. P\(_2\)O\(_5\)  
   diphosphorus pentoxide

4.68
a. selenium tetrafluoride  
   SeF\(_4\)  
   d. phosphorus trichloride  
   PCl\(_3\)  
   c. dinitrogen monoxide  
   N\(_2\)O
b. oxygen difluoride  
   OF\(_2\)  
   d. carbon diselenide  
   CSe\(_2\)
c. SiF\(_4\)  
   silicon tetrachloride

4.69
a. disulfur monoxide  
   S\(_2\)O  
   d. carbon diselenide  
   CSe\(_2\)
b. sulfur hexafluoride  
   SF\(_6\)  
   c. silicon tetrachloride  
   SiCl\(_4\)
Forces Between Particles  79

4.70  a. calcium and the hypochlorite ion  \( \text{Ca(ClO)}_2 \)  calcium hypochlorite
b. cesium and the nitrite ion  \( \text{CsNO}_2 \)  cesium nitrite
c. Mg and \( \text{SO}_3^{2-} \)  \( \text{MgSO}_3 \)  magnesium sulfite
d. K and \( \text{CrO}_7^{2-} \)  \( \text{K}_2\text{CrO}_7 \)  potassium dichromate

4.71  a. calcium and the phosphate ion  \( \text{Ca}_3(\text{PO}_4)_2 \)  calcium phosphate
b. cesium and the nitrite ion  \( \text{CsNO}_2 \)  cesium nitrite
c. Li and \( \text{CO}_3^{2-} \)  \( \text{Li}_2\text{CO}_3 \)  lithium carbonate
d. Na and \( \text{PO}_4^{3-} \)  \( \text{Na}_3\text{PO}_4 \)  sodium phosphate

4.72  a. magnesium hydroxide  \( \text{Mg(OH)}_2 \)  sodium hydrogen carbonate
b. calcium sulfite  \( \text{CaSO}_3 \)  sodium carbonate
c. ammonium phosphate  \( (\text{NH}_4)_3\text{PO}_4 \)  barium sulfate  \( \text{BaSO}_4 \)

4.73  a. potassium permanganate  \( \text{KMnO}_4 \)  ammonium dihydrogen phosphate  \( \text{NH}_4\text{H}_2\text{PO}_4 \)
b. calcium hydroxide  \( \text{Ca(OH)}_2 \)  calcium hypochlorite  \( \text{Ca(ClO)}_2 \)
c. calcium phosphate  \( \text{Ca}_3(\text{PO}_4)_2 \)

d. sodium hydrogen carbonate  \( \text{NaHCO}_3 \)  sodium phosphate

4.74  a. Any group I A (1) element and \( \text{SO}_3^{2-} \)  \( \text{M}_2\text{SO}_3 \)
b. Any group I A (1) element and \( \text{C}_2\text{H}_3\text{O}_2^- \)  \( \text{MC}_2\text{H}_3\text{O}_2 \)
c. Any metal that forms \( \text{M}^{2+} \) ions and \( \text{CrO}_7^{2-} \)  \( \text{M}_2\text{CrO}_7 \)
d. Any metal that forms \( \text{M}^{3+} \) ions and \( \text{PO}_4^{3-} \)  \( \text{MPO}_4 \)
e. Any metal that forms \( \text{M}^{3+} \) ions and \( \text{NO}_3^- \)  \( \text{M(NO}_3)_3 \)

4.75  a. Any group II A (2) element and \( \text{HSO}_3^- \)  \( \text{M}(_2\text{HSO}_3)_2 \)
b. Any group II A (2) element and \( \text{HPO}_4^{2-} \)  \( \text{M(HPO}_4)_2 \)
c. Any metal that forms \( \text{M}^+ \) ions and \( \text{NO}_3^- \)  \( \text{MNO}_2 \)
d. Any metal that forms \( \text{M}^{3+} \) ions and \( \text{CO}_3^{2-} \)  \( \text{M}_2(\text{CO}_3)_3 \)
e. Any metal that forms \( \text{M}^{2+} \) ions and \( \text{HPO}_4^{2-} \)  \( \text{MHPO}_4 \)

OTHER INTERPARTICLE FORCES (SECTION 4.11)

4.76  The alcohol has higher melting and boiling points than the ether. The forces that hold the alcohol molecules together must be stronger and harder to break than the forces that hold the ether molecules together.

4.77  
\[ \begin{align*} 
\text{H} & \quad \text{C} \quad \text{O} \quad \text{C} \quad \text{H} \\
\text{H} & \quad \text{H} \quad \text{H} 
\end{align*} \]
This is dimethyl ether. It experiences dipolar forces, which are weaker than the hydrogen bonding forces that ethyl alcohol experiences.

\[ \begin{align*} 
\text{H} & \quad \text{C} \quad \text{C} \quad \text{OH} \\
\text{H} & \quad \text{H} \quad \text{H} 
\end{align*} \]
This is ethyl alcohol. It experiences hydrogen bonding forces, which are stronger than the dipolar forces that dimethyl ether experiences.
The noble gases are nonpolar; therefore, they only experience dispersion forces. These forces increase with the size of the particles; therefore, the order of increasing boiling point for the noble gases is: helium, neon, argon, krypton, xenon, and radon.

CO\textsubscript{2} is a molecular solid with nonpolar molecules in the lattice sites held together by dispersion forces. SiO\textsubscript{2} is a covalent network solid because the lattice sites are occupied by atoms which are joined together by covalent bonds. Covalent bonds are much stronger than dispersion forces; consequently, SiO\textsubscript{2} has a much higher melting point than CO\textsubscript{2}.

Dispersion forces and dipolar forces are unlikely to be the predominant ones in the lattice of solid sucrose because these forces are relatively weak. Ionic bonds, metallic bonds, and covalent bonds are unlikely to be the predominant ones in the lattice of solid sucrose because they are very strong.

Solid sucrose is likely to experience hydrogen bonding as its predominant interparticle bonding because it contains many OH groups that are bonded to carbon atoms. This leads to a high melting point.

**ADDITIONAL EXERCISES**

Hydrogen is the element with an electronic configuration of 1s\textsuperscript{1}. Nitrogen is the element with the electronic configuration of 1s\textsuperscript{2} 2s\textsuperscript{2} 2p\textsuperscript{3}. The molecule that contains 3 hydrogen atoms and 1 nitrogen atom is NH\textsubscript{3}. They hydrogen bond to each other as shown here:

Magnesium is the element in group IIA(2) and period 3. Fluorine is the element with the electron configuration 1s\textsuperscript{2} 2s\textsuperscript{2} 2p\textsuperscript{5}. The formula for a compound made from these elements would be MgF\textsubscript{2}. magnesium fluoride.

When magnesium metal reacts with oxygen, magnesium oxide (MgO) is formed. The mass of 0.200 moles of MgO is calculated as follows:

\[
0.200 \text{ moles MgO} \left( \frac{40.31 \text{ g MgO}}{1 \text{ mole MgO}} \right) = 8.06 \text{ g MgO}
\]

1 ampere \( \left( \frac{6.2 \times 10^{18} \text{ electrons}}{1 \text{ ampere}} \right) \left( \frac{1 \text{ H atom}}{1 \text{ electron}} \right) \left( \frac{1.01 \text{ g H}}{6.02 \times 10^{23} \text{ atoms}} \right) = 1.0 \times 10^{-5} \text{ g H} \text{ s} \)

1.0x10\textsuperscript{-5} grams of hydrogen must be dissociated each second in a fuel cell to produce 1 ampere of electricity.

If one atom of oxygen reacted with two atoms of nitrogen to form a molecule, the formula of the molecule would be N\textsubscript{2}O. The electronegativity difference between nitrogen and oxygen is 0.5; therefore, the bond between nitrogen and oxygen is covalent. The name of N\textsubscript{2}O is dinitrogen monoxide.

**ALLIED HEALTH EXAM CONNECTION**

Noble gases (d) have low boiling points, are all gases at room temperature, and are also called inert gases.
Inert gases have \( (a) \) 8 electrons in its outermost energy level.

The type of bond formed when electrons are shared between two atoms is a \( (c) \) covalent bond.

\( \text{Li}_2\text{SO}_3 \) is \( (a) \) lithium sulfite.

An atom became an ion that possesses a negative charge, the atom must have \( (d) \) gained electrons.

When calcium reacts with chlorine to form calcium chloride, it \( (c) \) loses two electrons.

The probable charge for an ion formed from \( \text{Ca} \) is \( (b) +2 \).

A covalent bond is believed to be caused by a \( (b) \) sharing of electrons.

\( \text{Cl}_2 \) has a nonpolar bond in which the electrons are being shared equally.

The formula for bismuth (III) hydroxide is \( (b) \) \( \text{Bi(OH)}_3 \).

\( \text{NH}_4^+ \) will combine with a chloride ion to produce ammonium chloride.

When bromine and magnesium are reacted to form \( \text{MgBr}_2 \), an \( (c) \) ionic bond is formed. (Note: Answer is based on the generalization that a metal and nonmetal react to form an ionic bond.)

The parts of an atom directly involved in ionic bonding are the \( (c) \) electrons in the outer energy shell.

In forming an ionic bond with an atom of chlorine, a sodium atom will \( (c) \) give up 1 electron to the chlorine atom.

In bonding, the electrons of \( \text{K} \) and \( \text{Br} \) \( (a) \) would be transferred because potassium is a metal and bromine is a nonmetal.

\( \text{CO} \) contains a bond with the least ionic character because it contains a bond between two nonmetals, while all the other compounds contain a bond between a metal and a nonmetal.

\( \text{N}_2 \) is nonpolar.

\( \text{F}_2 \) is nonpolar and contains a nonpolar covalent bond.

\( \text{The bonding between two carbons} \) is a nonpolar covalent bond.

The type of bond that forms between two molecules of water is a \( (b) \) hydrogen bond.

The bond between the O of one water molecule and the H of a second water molecule is an example of hydrogen bonding.
CHEMISTRY FOR THOUGHT

4.108 Yes, a reaction similar to the one that occurs between sodium metal and chlorine gas would be expected to occur between potassium metal and fluorine gas because potassium is in the same group as sodium and fluorine is in the same group as chlorine. In fact, any combination of a metal from group IA (1) (lithium, sodium, potassium, rubidium, cesium, francium) and nonmetal from group VIIA (17) (fluorine, chlorine, bromine, iodine, astatine) should produce a similar reaction.

4.109 The colors of some compounds result from the presence of water in the compounds. To determine if the presence of water in a compound caused its color, heat the compound in a container which could capture any gases given off. If the water vapor were the only gas given off and the color changed, then it would be evident that the water produced the original color.

4.110 The central atom in the balloon models will always be at the point the balloons are tied together. A group of 5 balloons would have a triangular bipyramidal shape with 3 balloons forming a triangular shape in the middle and 2 balloons forming an axis perpendicular to the triangular shape. A group of 6 balloons would have an octahedral shape. If the center of the 6 balloons were placed in the middle of a cube, then the top of each balloon would be in the center of a cube face because the bond angles are all 90°.

4.111 Potassium carbonate is K₂CO₃. Potassium chromate is K₂CrO₄. Potassium phosphate is K₃PO₄. Potassium permanganate is KMnO₄. The colored compounds of potassium (K₂CrO₄ and KMnO₄) have a transition metal as part of the polyatomic ion; therefore, potassium dichromate (K₂Cr₂O₇) should also be a colored compound.

4.112 When a metal changes to form a positively charged metal ion, it loses electrons. The remaining electrons are then pulled closer to the positively charged nucleus, which makes the size of the metal ion smaller than the size of the original metal atom.

4.113 A negatively charged ion will be larger than a nonmetal atom of the same element, because as the electrons are added to the atom, the electron cloud will increase in size as the nucleus is not able to hold onto the electrons as well as their number increases.

4.114 Neon atoms do not combine to form Ne₂ molecules because each neon atom has a completed valence shell and does not need to form bonds with another atom in order to satisfy its valence.

4.115 CCl₄ molecules are nonpolar because the molecules are symmetrical. If a positively charged object were used in place of the balloon, the water molecules would still be attracted by the object and the carbon tetrachloride molecules would not be affected by the object.

4.116 When CH₄ is burned in air at a high temperature, CO₂ and H₂O are the primary products; however, air is mostly nitrogen and as the combustion occurs at high temperatures, free radical oxygen atoms produced during the reaction with methane can react with high temperature nitrogen molecules to produce NO as a side product.
EXAM QUESTIONS
MULTIPLE CHOICE

1. Which of the following distinguishing electron configurations is characteristic of noble gases?
   a. n^6
   b. nd^{10}
   c. n^6
   d. ns^2
   Answer: C

2. Which of the following would cause a calcium atom (Ca) to achieve a noble gas configuration?
   a. lose one electron
   b. lose two electrons
   c. gain one electron
   d. gain two electrons
   Answer: B

3. What is the formula weight of Ca(OH)_2?
   a. 57.1 u
   b. 58.1 u
   c. 74.1 u
   d. 114 u
   Answer: C

4. Which of the following has a noble gas electronic configuration?
   a. Cl
   b. O^-
   c. Br^-
   d. Cl^-
   Answer: C

5. When magnesium forms an ion, it would be represented as:
   a. Mg
   b. Mg^2+
   c. Mg^+
   d. Mg^{2+}
   Answer: D

6. Which of the following electronic changes will cause a Group VA (15) element to achieve a noble gas configuration?
   a. gain three electrons
   b. gain two electrons
   c. gain one electron
   d. lose three electrons
   Answer: A

7. The ionic compound that forms between magnesium (Mg) and oxygen (O) has the formula:
   a. MgO
   b. MgO
   c. MgO
   d. MgO
   Answer: B

8. When an ionic compound forms between sodium (Na) and bromine (Br) atoms, it is true that:
   a. a bromine atom donates an electron to a sodium atom.
   b. both the bromine atoms and sodium atoms donate electrons to each other.
   c. a sodium atom donates an electron to a bromine atom.
   d. neither bromine nor sodium atoms donate electrons to each other.
   Answer: C

9. The correct name for CeS is:
   a. cesium sulfate.
   b. cesium sulfide.
   c. cerium sulfate.
   d. cerium sulfide.
   Answer: D
10. The rigid three-dimensional arrangement assumed by the ions of ionic compounds is called a:
   a. molecule.  
   b. binary compound.  
   c. lattice site.  
   d. crystal lattice.
   Answer: D

11. Which of the following would you expect to be the most polar molecule?
   a. CO₂  
   b. H₂S  
   c. Cl₂  
   d. SiH₄
   Answer: B

12. Which of the following is a correct electron dot formula for a group IIIA (13) element M?
   a.  
   b.  
   c.  
   d.  
   Answer: D

13. Which of the following is a correct electron dot formula for ICl?
   a.  
   b.  
   c.  
   d.  
   Answer: A

14. A covalent bond results when:
   a. one atom gives up an electron to another atom.
   b. one atom gives up two electrons to another atom.
   c. two atoms share a pair of electrons.
   d. two atoms share a single electron.
   Answer: C

15. Which of the following is the correct electron dot formula of C₂H₄?
   a.  
   b.  
   c.  
   d.  
   Answer: A

16. Which of the following statements is correct with reference to covalent bonding?
   a. Covalent bonds only form between like atoms.
   b. The truly covalent bond is the reason for hydrogen bonding.
   c. Polyatomic compounds contain only covalent bonds.
   d. None of these is a correct statement.
   Answer: D

17. Which of the following has the highest electronegativity?
   a. O  
   b. N  
   c. Si  
   d. P
   Answer: A

18. If the electronegativity difference between A and B is 0.8, what type of bond is formed between the two elements?
   a. polar covalent  
   b. nonpolar covalent  
   c. ionic  
   d. metallic
   Answer: A
19. Which of the following pairs of elements is most likely to form a covalent bond?
   a. Fe and H   b. Cs and Br   c. Cl and O   d. Zn and S
   Answer: C

20. Which of the following covalent molecules contains polar bonds?
   a. O≡C   b. H—H   c. H—Cl   d. more than one response is correct
   Answer: D

21. The correct name for the covalent compound N₂O₄ is:
   a. dinitrogen tetroxide.   b. nitrogen oxide.   c. nitrogen quartoxide.   d. dinitrogen quartoxide.
   Answer: A

22. Which of the following molecular geometries would most likely give rise to a nonpolar compound?
   a.  
   b.  
   c.  
   d.  
   Answer: A

23. The correct formula for the ionic compound containing Al³⁺ and PO₄³⁻ is:
   a. Al₃(PO₄)₃   b. Al₂PO₄   c. Al₄(PO₄)₂   d. Al₂(PO₄)₃
   Answer: B

24. The correct formula for an ionic compound containing Fe²⁺ and ClO₄⁻ is:
   a. FeClO₄   b. Fe₂(CIO₄)₃   c. Fe(ClO₄)₂   d. Fe₃(ClO₄)₂
   Answer: C

25. The correct formula for ammonium sulfate is:
   a. NH₄SO₄   b. (NH₄)₂SO₄   c. NH₄(SO₄)₂   d. (NH₄)₃(SO₄)₃
   Answer: B

26. The correct name for BaCO₃ is:
   a. barium trioxide.   b. barium monooxide.   c. barium carbonate.   d. barium monocarbonate.
   Answer: C

27. In describing the strength of interparticle forces, we discover that the weakest forces or bonds are:
   a. covalent.   b. metallic.   c. dipolar.   d. dispersion.
   Answer: D

28. Which interparticle forces would you expect to find in a sample of the element lithium?
   a. covalent.   b. dispersion forces.   c. ionic.   d. metallic.
   Answer: D
29. The molecular structure of water should be:
   a. linear because of the electron configuration of the oxygen atom.
   b. trigonal planer because water contains 3 atoms.
   c. bent because of the non-bonded electrons on the molecule.
   d. undetermined as there is no way to predict the shape of the water molecule.

   Answer: C

30. Which of the following correctly illustrates hydrogen bonding in water?
   a. \[
   \begin{array}{c}
   H \cdot O \cdot O \cdot H \\
   \text{b. } H \cdot O \cdot H \\
   H \cdot H \\
   \end{array}
   \]
   b. \[
   \begin{array}{c}
   H \cdot O \cdot H \\
   H \cdot H \\
   \end{array}
   \]
   c. \[
   \begin{array}{c}
   H \cdot O \cdot O \cdot H \\
   \end{array}
   \]
   d. \[
   \begin{array}{c}
   H \cdot O \\
   \end{array}
   \]

   Answer: A

31. Hydrogen bonds form between the molecules of the hypothetical compound ABCH and do not form between DEFH molecules. Which of the following is true?
   a. ABCH has a higher molecular weight than DEFH.
   b. The chemical bonds in ABCH tend to be more polar than in DEFH.
   c. ABCH tends to be a compound with color, and DEFH does not have color.
   d. There is no significant difference between ABCH and DEFH.

   Answer: B

32. Which type of interparticle forces leads to compounds with the lowest melting points?
   a. covalent.
   b. dispersion forces.
   c. ionic.
   d. metallic.

   Answer: B

33. The correct name for K₂SO₄ is:
   a. potassium sulfate.
   b. potassium sulfide.
   c. potassium sulfite.
   d. potassium tetrasulfoxygen.

   Answer: A

34. A polar molecule must have:
   a. polar bonds.
   b. an unsymmetric arrangement of bonds.
   c. neither a) nor b)
   d. both a) and b)

   Answer: D

35. The correct name for KHPO₄ is:
   a. potassium phosphate.
   b. monopotassium phosphate.
   c. potassium hydrogen phosphate.
   d. KHPO₄ is not a compound.

   Answer: C

36. Which of the following would be a polar molecule?
   a. O₂
   b. HCl
   c. CH₄
   d. F₂

   Answer: B
37. Which of the following is the polyatomic ion named carbonate?
   a. $\text{Cl}_2\text{Cl}^+$  
   b. $\text{ClO}^-$  
   c. $\text{CO}_3^{2-}$  
   d. $\text{HCO}_3^-$
   Answer: C

38. The shape of a $\text{BF}_3$ molecule is:
   a. angular.  
   b. trigonal planar.  
   c. trigonal pyramid.  
   d. tetrahedral.
   Answer: B

39. Which of the following metals would not use a Roman numeral as part of its name in a compound?
   a. Cr  
   b. Mn  
   c. Co  
   d. Ca
   Answer: D

40. The anion in an ionic compound whose name ends in “-ide” is:
   a. always a simple ion.  
   b. always a polyatomic ion.  
   c. either a simple or polyatomic ion.  
   d. a positive charge.
   Answer: C

41. What medicinal value does ZnO have?
   a. sun screen  
   b. relieves diaper rash  
   c. relieves poison ivy  
   d. all of these
   Answer: D

42. Which pair of elements will be further apart in electronegativity?
   a. Cl and F  
   b. Li and Cl  
   c. Mn and Se  
   d. U and Cs
   Answer: B

43. In what part of the human body is nitric oxide, NO, produced?
   a. the brain  
   b. the heart  
   c. blood vessels  
   d. the skin
   Answer: C

44. Which of the following represents a polar covalent molecule?
   a. $\text{NaCl}$  
   b. $\text{CH}_3\text{Cl}$  
   c. $\text{KCl}$  
   d. $\text{CaCl}_2$
   Answer: B

45. What would be the proper name for the binary ionic compound CaBr$_2$?
   a. calcium dibromine  
   b. monocalcium bromine  
   c. monocalcium dibromide  
   d. calcium bromide
   Answer: D

46. NH$_3$ (ammonia) would have what structure according to VSEPR theory?
   a. triangle  
   b. pyramid with square base  
   c. pyramid with triangular base  
   d. none of these
   Answer: C

47. Atoms or ions are considered isoelectronic if:
   a. they have similar electron configurations.  
   b. they have different number of electrons.  
   c. they have the same number of protons.  
   d. none of the above
   Answer: D
48. The lattice site in a crystal is:
   a. the general location of all particles in a crystal.
   b. the individual location occupied by a particle in a crystal lattice.
   c. the rigid three-dimensional arrangement of particles.
   d. none of the above

   Answer: B

TRUE-FALSE

1. Oxygen must gain two electrons to achieve a noble gas configuration.

   Answer: T

2. Calcium must gain two electrons to achieve a noble gas configuration.

   Answer: F

3. O₂ contains an ionic bond.

   Answer: F

4. Fe²⁺ and Fe³⁺ are isoelectronic.

   Answer: F

5. Na⁺ and F⁻ are isoelectronic.

   Answer: T

6. K⁺ and Cl⁻ have the same electronic configuration as argon.

   Answer: T

7. Carbon dioxide is a linear molecule.

   Answer: T

8. Ammonia is a planar trigonal molecule.

   Answer: F

9. The water molecule has a bent structure.

   Answer: T

10. CCl₄ has a tetrahedral structure.

    Answer: T

11. Both bonding and non-bonding electron pairs can influence molecular shape.

    Answer: T

12. Dispersion forces are among the strongest interparticle forces.

    Answer: F

13. HCl and HBr can exhibit hydrogen bonding with each other.

    Answer: F

14. Only compounds containing hydrogen covalently bonded to an oxygen, nitrogen, or fluoride atom can exhibit hydrogen bonding.

    Answer: T
15. Metals gain electrons to become ions in ionic compounds.
   Answer: F

16. H₂O is a binary compound.
   Answer: T

17. Nitrogen is more electronegative than oxygen.
   Answer: F

18. In one system of naming multiple cations of an element, the cation with the higher charge is used to indicate the cation with the higher charge.
   Answer: T

19. The ammonium ion contains polar covalent bonds.
   Answer: T

20. A double bond contains a three shared pairs of electrons.
   Answer: F